

# Contents

Foreword .....	ix
Acknowledgments .....	xi
Acronyms .....	xiii
<b>Executive Summary .....</b>	<b>ES-1</b>
<b>Chapter 1—Introduction.....</b>	<b>1-1</b>
Background .....	1-2
Study Approach .....	1-4
The First Leg: An Examination of BOD Loadings Before and After the CWA .....	1-5
The Second Leg: An Examination of “Worst-Case” DO in Waterways	
Below Point Sources Before and After the CWA .....	1-6
The Third Leg: Case Study Assessments of Water Quality .....	1-12
The Audience For This Report .....	1-13
References .....	1-14
<b>Chapter 2—An Examination of BOD Loadings Before and After the CWA .....</b>	<b>2-1</b>
A. Historical Consequences of Ignoring the Wastewater Treatment Component of the Urban Water Cycle .....	2-2
<i>Impacts on Water Supply Users and “The Great Sanitary Awakening” .....</i>	2-3
<i>Impacts on Water Resource Users .....</i>	2-5
B. Evolution of Wastewater and the Use of DO and BOD as Indicators of Water Quality .....	2-7
<i>Primary Treatment.....</i>	2-7
<i>Dissolved Oxygen as an Indicator of Water Quality .....</i>	2-7
<i>Secondary Treatment .....</i>	2-9
<i>Biochemical Oxygen Demand (BOD) as a Measure of Organic Wasteload Strength .....</i>	2-10
C. The Federal Role in Implementing Secondary Treatment in the Nation’s POTWs .....	2-11
<i>The Federal Role in Secondary Treatment Before the Clean Water Act .....</i>	2-11
<i>The Federal Role in Secondary Treatment After the Clean Water Act.....</i>	2-18
D. Nationwide Trends in BOD Loading Based on Population and POTW Treatment Design .....	2-26
<i>Types of BOD Reported in This Trends Analysis .....</i>	2-28
<i>Trends in POTW Inventory .....</i>	2-31
<i>Trends in Population and Influent Wastewater Flow to POTWs .....</i>	2-32
<i>Trends in Influent BOD Loading to POTWs .....</i>	2-35
<i>Trends in Effluent BOD Loading from POTWs .....</i>	2-38
<i>Trends in BOD Removal Efficiency.....</i>	2-43
<i>Future Trends in BOD Effluent Loading .....</i>	2-45
E. Comparison of Contemporary BOD <sub>5</sub> Loadings From POTWs and Other Point and Nonpoint Sources Based on Estimates of Actual Loadings .....	2-48
<i>Pollutant Loading From Sources Other Than POTWs .....</i>	2-49
<i>Estimates of Contemporary (ca. 1995) BOD<sub>5</sub> Loading Using the National Water             Pollution Control Assessment Model (NWPCAM) .....</i>	2-53
<i>Comparison of Point and Nonpoint Sources of BOD<sub>5</sub> at the National Level .....</i>	2-63
F. Investment Costs for Water Pollution Control Infrastructure .....	2-63
<i>The Construction Grants Program.....</i>	2-63

<i>Other Investment Cost for Water Pollution Control Infrastructure</i> .....	2-66	
<i>Future Infrastructure Needs</i> .....	2-67	
G. Summary, Conclusions, and Future Trends .....	2-68	
<i>Key Points of the Background Sections</i> .....	2-68	
<i>Key Points of the BOD Loading Analysis Sections</i> .....	2-69	
<i>Key Points of the Investment Costs Section</i> .....	2-71	
<i>Conclusions and Future Trends</i> .....	2-72	
References .....	2-73	
<b>Chapter 3—An Examination of “Worst-Case” DO in Waterways Below Point Sources</b>		
<b>Before and After the CWA</b> .....		<b>3-1</b>
A. Background .....	3-2	
<i>Sources of DO Data</i> .....	3-3	
“Worst Case” Conditions as a Screening Tool .....	3-5	
<i>The Role of Spatial Scale in This Analysis</i> .....	3-12	
B. Data Mining .....	3-13	
<i>Step 1—Data Selection Rules</i> .....	3-13	
<i>Step 2—Data Aggregation Rules From a Temporal Perspective</i> .....	3-14	
<i>Step 3—Calculation of the Worst-Case DO Summary Statistic Rules</i> .....	3-14	
<i>Step 4—Spatial Assessment Rules</i> .....	3-15	
<i>Step 5—Data Aggregation Rules From a Spatial Perspective</i> .....	3-18	
<i>Step 6—Development of the Paired Data Sets (at each spatial scale)</i> .....	3-19	
C. Comparison of Worst-Case DO in Waterways Below Point Source Discharges		
Before and After the CWA at Three Spatial Scales .....	3-20	
<i>Reach Scale</i> .....	3-20	
<i>Catalog Unit Scale</i> .....	3-25	
<i>Comparison of the Change in Signal Between the Reach and Catalog Unit Scales</i> <i>Using the Upper White River Basin (Indiana) as an Example</i> .....	3-33	
<i>Major River Basins</i> .....	3-38	
D. Summary and Conclusions .....	3-43	
<i>Key Points of the Background Section</i> .....	3-43	
<i>Key Points of the Data Mining Section</i> .....	3-44	
<i>Key Points of the Comparative Analysis Section</i> .....	3-45	
<i>Conclusions</i> .....	3-47	
References .....	3-51	
<b>Chapter 4—Case Study Assessments of Water Quality</b> .....		<b>4-1</b>
A. Background .....	4-2	
B. Selection of Case Study Waterways .....	4-4	
C. Before and After CWA .....	4-6	
D. Policy Scenarios for Municipal Effluent Discharges .....	4-8	
E. Discussion and Conclusions .....	4-10	
References .....	4-12	
<b>Chapter 5—Connecticut River Case Study</b> .....		<b>5-1</b>
Background .....	5-1	
Physical Setting and Hydrology .....	5-2	
Population, Water, and Land Use Trends .....	5-4	
Historical Water Quality Issues .....	5-5	
Legislative and Regulatory History .....	5-6	
Impacts of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	5-6	

Impacts of Wastewater Treatment: Recreational and Living Resources Trends .....	5-9
Summary and Conclusions .....	5-10
References .....	5-11
<b>Chapter 6<sup>4</sup>Hudson-Raritan Estuary Case Study .....</b>	<b>6-1</b>
Background .....	6-1
Physical Setting and Hydrology .....	6-2
Population, Water, and Land Use Trends .....	6-4
Historical Water Quality Issues .....	6-6
Legislative and Regulatory History .....	6-9
Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	6-10
Impact of Wastewater Treatment: Recreational and Living Resources Trends .....	6-20
Summary and Conclusions .....	6-25
References .....	6-27
<b>Chapter 7<sup>4</sup>Delaware Estuary Case Study .....</b>	<b>7-1</b>
Physical Setting and Hydrology .....	7-2
Population, Water, and Land Use Trends .....	7-4
Historical Water Quality Issues .....	7-6
Legislative and Regulatory History .....	7-7
Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	7-8
Evaluation of Water Quality Benefits Following Treatment Plant Upgrade .....	7-13
Impact of Wastewater Treatment: Recreational and Living Resources Trends .....	7-17
Summary and Conclusions .....	7-21
References .....	7-23
<b>Chapter 8<sup>4</sup>Potomac Estuary Case Study .....</b>	<b>8-1</b>
Physical Setting and Hydrology .....	8-3
Population, Water, and Land Use Trends .....	8-4
Historical Water Quality Issues .....	8-5
Legislative & Regulatory History .....	8-5
Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	8-6
Evaluation of Water Quality Benefits Following Treatment Plant Upgrades .....	8-8
Impact of Wastewater Treatment: Recreational and Living Resources Trends .....	8-11
Designated Uses & Bacterial Trends .....	8-11
Submerged Aquatic Vegetation, Fishery, and Waterfowl Resources .....	8-12
Trends In Suspended Solids Load and Water Clarity .....	8-13
SAV and Ecological Resources .....	8-18
Summary and Conclusions .....	8-18
References .....	8-18
<b>Chapter 9<sup>4</sup>James River Estuary Case Study .....</b>	<b>9-1</b>
Physical Setting and Hydrology .....	9-1
Population Trends .....	9-3
Historical Water Quality Issues .....	9-5
Legislative and Regulatory History .....	9-5
Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	9-6
Evaluation of Water Quality Benefits Following Treatment Plant Upgrades .....	9-11
Impact of Wastewater Treatment: Recreational and Living Resources Trends .....	9-13
Summary and Conclusions .....	9-14
References .....	9-15

<b>Chapter 10<sup>4</sup><sub>3</sub>Upper Chattahoochee River Case Study .....</b>	<b>10-1</b>
Physical Setting and Hydrology .....	10-2
Population, Water, and Land Use Trends .....	10-4
Historical Water Quality Issues .....	10-6
Legislative and Regulatory History .....	10-7
Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	10-9
Impact of Wastewater Treatment: Recreational and Living Resources Trends .....	10-12
Summary and Conclusions .....	10-13
References .....	10-14
<b>Chapter 11<sup>4</sup><sub>3</sub>Ohio River Case Study .....</b>	<b>11-1</b>
Physical Setting and Hydrology .....	11-2
Population, Water, and Land Use Trends .....	11-4
Historical Water Quality Issues .....	11-5
Legislative and Regulatory History .....	11-5
Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	11-7
Impact of Wastewater Treatment: Recreational and Living Resources Trends .....	11-10
Summary and Conclusions .....	11-12
References .....	11-12
<b>Chapter 12<sup>4</sup><sub>3</sub>Upper Mississippi River Case Study .....</b>	<b>12-1</b>
Physical Setting and Hydrology .....	12-2
Population, Water, and Land Use Trends .....	12-5
Historical Water Quality Issues .....	12-6
Legislative and Regulatory History .....	12-10
Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	12-12
Evaluation of Water Quality Benefits Following Treatment Plant Upgrades .....	12-20
Impact of Wastewater Treatment: Recreational and Living Resources Trends .....	12-23
Summary and Conclusions .....	12-26
References .....	12-29
<b>Chapter 13<sup>4</sup><sub>3</sub>Willamette River Case Study .....</b>	<b>13-1</b>
Physical Setting and Hydrology .....	13-2
Population, Water, and Land Use Trends .....	13-4
Historical Water Quality Issues .....	13-5
Legislative and Regulatory History .....	13-6
Impact of Wastewater Treatment: Pollutant Loading and Water Quality Trends .....	13-7
Impact of Wastewater Treatment: Recreational and Living Resources Trends .....	13-9
Summary and Conclusions .....	13-11
References .....	13-11

Appendix A—Summary of Peer Review Team Comments and Study Authors' Responses

Appendix B—National Municipal Wastewater Inventory and Infrastructure, 1940 to 2016

Appendix C—National Public and Private Sector Investment in Water Pollution Control

Appendix D—Before and After CWA Changes in 10th Percentile Dissolved Oxygen and 90th Percentile

BOD<sub>5</sub> at the Catalog Unit Level

Appendix E—Before and After CWA Changes in 10th Percentile Dissolved Oxygen at the RF1 Reach Level

Glossary